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ABSTRACT

First, this paper presents a briefing of the basic concepts of the INMARSAT TT&C and Communications Network which includes the space segment and the ground segment. The Network consists of the satellite control center, the TT&C stations and the corresponding TT&C subsystems of the INMARSAT satellites. Next, this paper describes the configuration, the functions and the performance indicators of the Beijing INMARSAT TT&C station. Finally, the primary technical characteristics of this station are presented.

Key words: Ground TT&C system, satellite ground protective equipment, ground station, antenna system.

The International Maritime Satellite (INMARSAT) Beijing Telemetry, Tracking, and Control (TT&C) Station was begun in late 1985. After bidding, design and acceptance, it formally was reviewed and accepted on May 1, 1991, and on September 1, 1990, it formally went operational as a second-generation INMARSAT TT&C station. It is the first TT&C station successfully bid by China. It is also the first international TT&C station in China designed and accepted in accordance with international standards and which

served as a maritime satellite international TT&C network main station.

In a number of maritime satellite TT&C missions, the Beijing INMARSAT TT&C station has always performed in an outstanding manner, smoothly completing the launch support and fixed point mission for maritime satellites. This was especially so in the F3 satellite TT&C mission on December 17, 1991, where it was even more outstanding in accomplishing its mission of satellite orbit-shifting, intermediate-orbit and moving-orbit tracking TT&C in the initial position-fixing and the orbital-testing mission as well as the final satellite-moving and position-fixing mission. This began the Beijing INMARSAT TT&C station long term fixed-position management, testing, and control mission.

I. Second-generation INMARSAT TT&C Network

The INMARSAT organization was established in 1979. Since it began using leasing of other international organization satellites (INTELSAT and ESA) for communications as well as ground stations and coastal stations of signatory countries it has achieved a first-generation international maritime satellite TT&C network. Since 1990, this organization has used its own satellites and TT&C stations to achieve the second-generation INMARSAT TT&C network. The worldwide coverage of this network is shown in Fig. 1.

1. Space Portions

This portion is composed of four satellites:

- The Indian Ocean satellite (F_1) 64.5°E
- The West Atlantic satellite (F_2) 15.0°W
- The Pacific satellite (F_3) 178.0° E
- The East Atlantic satellite (F_4) 55.0° W

The second-generation INMARSAT satellite is shown in Fig. 2.

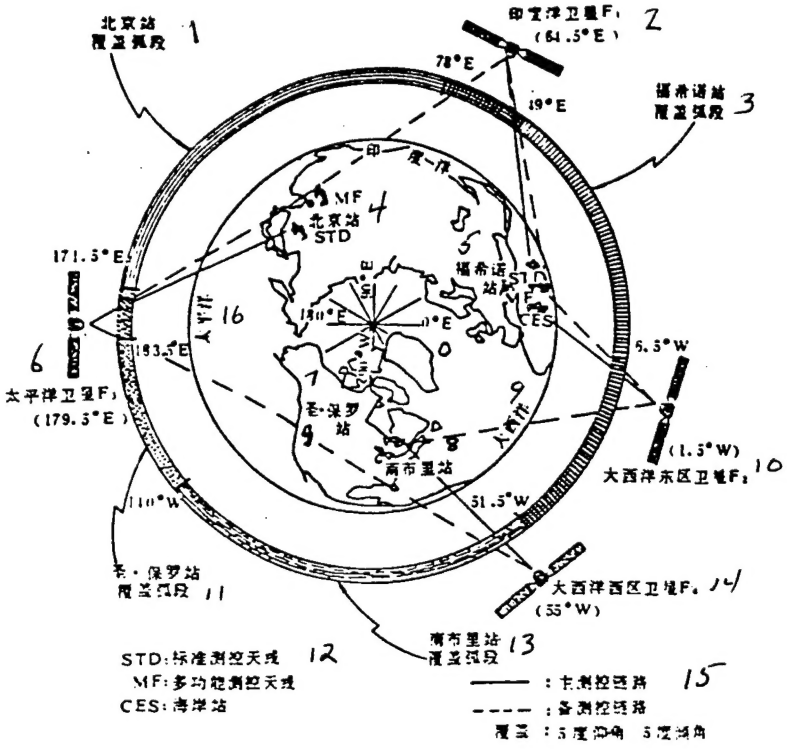

Fig. 1. Second-generation INMARSAT TT&C network coverage map 1 - Beijing station coverage arc 2 - Indian Ocean satellite F_1 (64.5°E) 3 - Frosinone station coverage arc 4 - MF Beijing station STD 5 - Frosinone station STD 6 - Pacific satellite F_3 (179.5°E) 7 - St. Paul station 8 - Southport station 9 - Atlantic Ocean 10 - East Atlantic satellite (F_2) 15.0°W 11 - St. Paul station coverage arc 12 - STD: Standard testing and control antenna, MF: Multifunctional antenna, CES: Coastal station 13 - Southport station coverage arc 14 - Western Atlantic satellite (F_4) 55.0°W 15 - Solid line is primary coverage, dotted line is reserve coverage, coverage is 5^0 angle of elevation and 5^0 angle of inclination 16 - Pacific Ocean

2. GROUND PORTIONS

This portion is composed of the following:

• TT&C stations: The Beijing Station, the Frosinone Station Italy, the St. Paul and Southport Stations in the United States

• Coastal stations (CES): INMARSAT nation communications ground stations.

• Mobile stations (SES): Various customer stations (ships and aircraft.

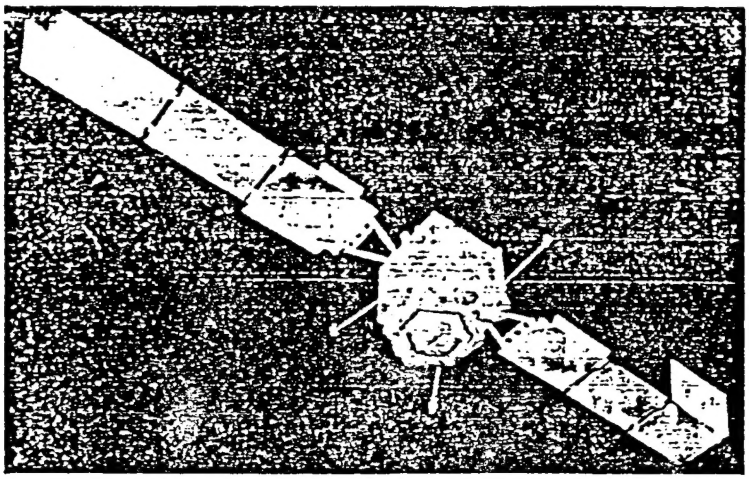

Fig. 2: Shape of second-generation INMARSATs

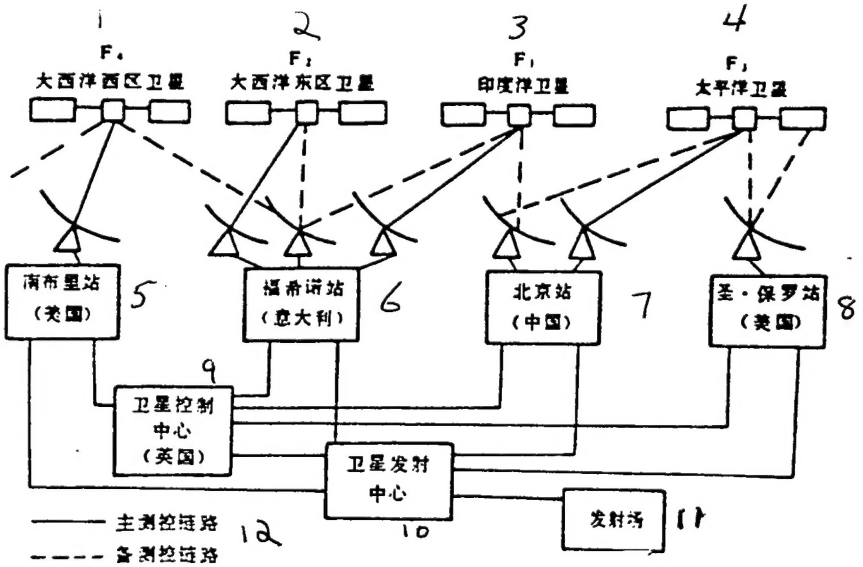

Fig. 3: Second-generation INMARSAT TT&C network diagram
1. F_1, West Atlantic Satellite. 2. F_2, East Atlantic Satellite. 3. F_3, Indian Ocean Satellite. 4. F_4, Pacific Satellite. 5. Southport Station (U.S.). 6. Frosinone Station (Italy). 7. Beijing Station (China). 8. St. Paul Station (U.S.). 9. Satellite Control Center (England). 10. Satellite Launch Center. 11. Launch site. 12. Solid lines are main TT&C lines, dotted lines are reserve TT&C lines.

Satellite control stations (SCC): INMARSAT Headquarters in London, England.

The coastal stations and mobile stations are used for maritime communications missions. The satellite engineering TT&C missions are accomplished through coordination between the TT&C subsystems on the satellite (TT&C responders) and the TT&C stations and the control center. The organization of the INMARSAT TT&C network is shown in Fig. 3.

II. Beijing INMARSAT TT&C Station

(1) Layout

This station includes a standard TT&C antenna system and a multifunctional antenna system. The former is used to conduct the fixed-position maintenance mission, while the latter is used for satellite launch TT&C support and satellite fixed-position TT&C reserve. At the same time it can also be used for satellite-orbit testing, communications-system monitoring and coastal station network entry verification.

The Beijing TT&C station is pictured on the cover of this issue. The configuration of the Beijing TT&C station is shown in Fig. 4.

Each antenna system includes the following subsystems:

1. Antenna servo and feeder system

The standard antenna is a "C" band 12 meter wheel-rail type antenna. The multifunctional antenna is a C/L dual-band 15-m rotating type antenna. This subsystem includes the antenna mechanism drive portion, the feeder source, the axial angle coder and the antenna servo drive. Its primary function is to drive the antenna to point toward the satellite, to collect signal energy from the satellite, and to transmit signal energy up to

the satellite. In addition, it also performs angular measurements.

2. Tracking subsystem

This subsystem includes the tracking frequency converters, the tracking decoder, the automatic phase-correction elements, antenna-correction elements and their connections. It primarily acquires tracking of the satellite and performs angular measurements.

3. Transmission subsystem

This subsystem is primarily a high-power amplifier. It amplifies the transmission frequency signal in order to meet equivalent omnidirectional radiation power (EIRP) requirements. This subsystem is deployed in two sets, one on-line and one in reserve.

4. Receiving subsystem

This system is primarily a low-noise amplifier. Under conditions of low quality factors (G/T) it amplifies the transmission signal to meet the needs of the power requirements at the intermediate-frequency connection. This subsystem is in two sets, one on-line and one in reserve.

5. Frequency-converter subsystem

This subsystem includes an upper and lower frequency converter. It converts the intermediate frequency and transmission frequencies of the upper and lower signals. The TT&C converter is a combination of on-line and standby sets with automatic switching between them. The orbit testing function converter is a single fixed-tone converter.

6. Monitoring and control subsystem

This is composed of a forward-position set and a rear-position set, connecting elements, two control sets and a

printer. The primary sets are doubled up, one on-line and one in reserve, and they can also be used for two- set communications. This subsystem performs monitor and control of the equipment within the station, monitoring of antenna type and directional data, antenna-angle data smoothness and adds time signals as well as data communications between the computers within the station and the computers checking the orbit.

7. 5MHz frequency source subsystem

This is the standard-frequency source which provides a reference frequency for all the equipment within the station. All equipment in the station which has anything to do with frequencies can lock onto this frequency source.

8. Base band subsystem

This subsystem includes three sets of ranging, distant measurement and remote control chains. These form a three-to-two reserve arrangement (that is, each antenna one chain, the other two are reserve chains). Each chain is composed of remote control elements, FM modulators, distant measurement elements, distant measurement/ranging receivers, timing elements, FM/PS converters, monitoring and control elements and a number of switching matrices.

The primary function of this subsystem is to generate a ranging signal, extract the corresponding time delay from the returning ranging signal, modulate the remote control command signals onto the intermediate and carrier frequencies, demodulate the intermediate frequency signals for distant measurement data and to properly connect the signals coming from and going to the appropriate antennas. In addition, it also adds a time flag to its data.

9. Port computer subsystem

This subsystem maintains compatibility between the multiple

satellite support systems in the Satellite Control Center and the TT&C stations (that is, the compatibility of the reference band systems and the monitoring and control systems). So-called compatibility is the HDLC and X.25 data exchange. Each port computer is connected to data circuits through communications data equipment (ECTD).

It is a Micro-VAX small computer and has a KA360 central processor, floating point processor and 5MB of RAM memory. In addition, it is also equipped with five hard disks and a magnetic tape recorder for data filing as well as a printer and display terminal.

10. In-orbit testing subsystem

This subsystem conducts in-orbit testing of satellites, their effective loading and conventional monitoring, checks abnormal states, communication and provides support for communications and monitoring and for coastal station testing.

This system includes the four following portions:

· Computer system. This controls the other portions and performs data analysis and provides data storage and access between local and distant users.

· Marking and calibration system. This includes the equipment which generates the test signal and the switchboard.

· Test portion. This includes the switching equipment, the transmission equipment, the spectrum analyzer and the dynamoscope for signal testing.

11. Communications subsystem

This includes the station's internal communications and interstation communications. There are two links between the Beijing TT&C Station and the Satellite Control Center in London:

one is an analog link (M1020 circuit) through the Ministry of Post and Telecommunications using the Indian Ocean satellite at 60° East, and the other is through the data link (64K circuit) of its own communications ground station through the Indian Ocean 63° East satellite. The former transmits data and the later transmits data and voice. The data link is arranged in-house while the voice links are arranged by public telephone.

12. Test equipment for marking and calibration

There are three zero-range transponders; a C-band radio frequency zero-range testing ring is constructed by equipping one of the three transponders with a multifunctional antenna. Another C-band wired transmission frequency zero-range testing ring is constructed by equipping another transponder with a standard tracking and control antenna. The third transponder is installed on a marking and calibration tower, capable of carrying out zero-range marking and calibration with the two above-mentioned antenna sets. During emergencies, this can be used as a backup for the zero-range transponders with two antenna sets. In addition, there is an L→C/C→L transponder, thus forming a signal-testing ring of L→C and C→L frequency bands.

13. Common-use utilities

Common-use utilities include an uninterruptible power supply (UPS), as well as the power supply system, air conditioning system, and firefighting system. These facilities ensure uninterrupted power supply, environmental temperature, and safety of the TT&C.

(2) Functions

There are the following functions for the standard TT&C station:

1. The data circuits accept command signals from the Satellite Control Center and relays the signals to the satellite.

2. As a backup for the Satellite Control Center, the station transmits local commands.

3. The station accepts remote measurement signals from the satellite and relays them to the Satellite Control Center via the data circuits.

4. As the backup of the Satellite Control Center, the station files local remote measurement data. Afterwards, the data are relayed to the Satellite Control Center via the data circuits.

5. According to commands from the Satellite Control Center, or manually-controlled commands from the station monitoring and control system, distance measurements from the satellite are carried out by using the sidetone ranging system. The data are relayed to the Satellite Control Center via the data circuits.

6. As a backup, the station conducts local ranging of the satellite.

7. Through the data circuits, the station's status of radio-frequency equipment, antenna-orientation angular data, and the status of the tracking system are relayed to the Satellite Control Center.

8. Besides the above-mentioned functions, the multifunctional station can also accomplish the following functions:
a. Via the data circuits, remote control of antenna orientation and tracking of the station is conducted by the Satellite Control Center.
b. By using the in-orbit test subsystem of the station, in-orbit measurement and testing of the satellite payload is conducted, in addition to the next regular monitoring.
c. Monitoring of the satellite communication system is carried out.

d. Repositioning of the satellite is supported.
e. The station is used as a backup for the standard TT&C station.
f. Support for launch, measurement, and control for satellite orbit transfers, transition orbits, and drifting orbits.
g. The station provides simultaneous measurement and control of the satellite, and in-orbit measurement and testing.

(3) Performance Indicators

III. Main Technical Properties of Beijing TT&C Station

1. High-technical iIndicators of the Beijing TT&C station correspond to (some items are better than) those at the Frosinone TT&C station in Italy. In particuar, technical indicators such as system-gain stability, group-delay stability, phase noise, and terminal-to-terminal code error rate in communication circuitry are better than those in TT&C stations previously erected in China.

2. High system reliability of the communication chain should attain 99.5% in a year, and the serviceability of system communication chains should be as high as 99.8% in a year. Therefore, besides the tracking communication chains and some in-orbit test chains, all other equipment items are laid out with two sets of warmup backup.

3. High requirements on environmental conditions

The temperature in the equipment room and in the antenna frame room should be controlled to within plus or minus 2^{0}C of the radiated temperature. This arrangement serves mainly to ensure the gain-stability requiremens of the entire system.

Indicators for the main technical performance of the Beijing TT&C station are listed in the table on the second following page.

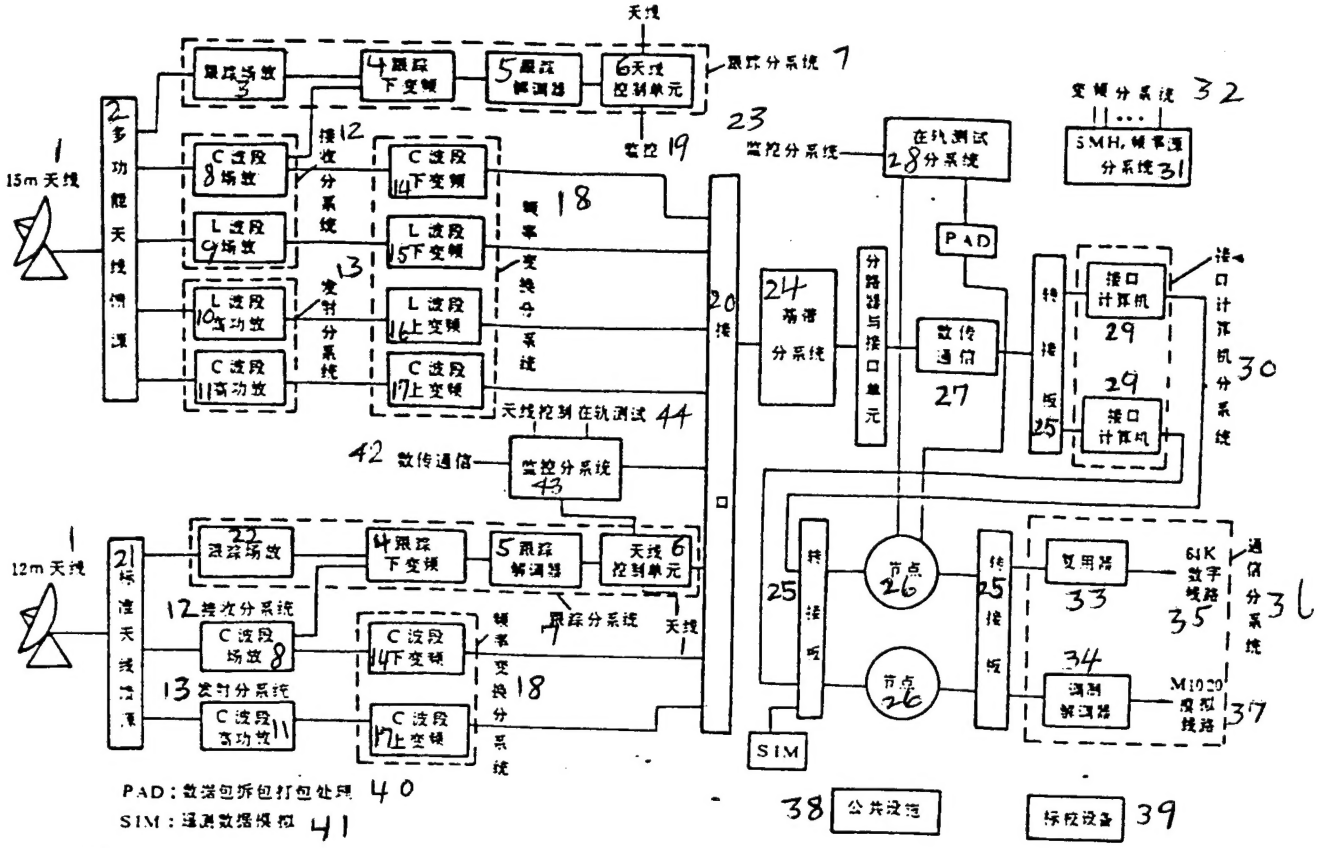

Fig. 4. Block Diagram for Beijing TT&C Station
KEY: 1 - Antenna 2 - Multifunctional antenna feed source 3 - Transmission by tracking field 4 - Down conversion of tracking 5 - Tracking demodulator 6 - Antenna control element 7 - Tracking subsystem 8 - Field transmission of C-band 9 - Field transmission of L-band 10 - High-power transmission of L-band 11 - High-power transmission of C-band 12 - Receiving subsystem 13 - Transmission subsystem 14 - Down-conversion of C-band 15 - Down-conversion of L-band 16 - Up-conversion of L-band 17 - Up conversion of C-band 18 - Frequency-transfer subsystem 19 - Monitoring and control 20 - Interface 21 - Standard antenna feed source 22 - Transmission of tracking field 23 - Monitoring and control subsystem 24 - Base band subsystem 25 - Switchboard 26 - Nodal point 27 - Data transmission communication 28 - In-orbit test subsystem 29 - Interface computer 30 - Interface computer subsystem 31 - Frequency source subsystem 32 - Variable frequency subsystem 33 - Repeater 34 - Modem 35 - 64K digital circuits 36 - Communication subsystem 37 - Analog circuits 38 - Common-use utilities 39 - Marking and calibration equipment 40 - Unpacking and packing of data packet 41 - Remote-sensing data simulation 42 - Data communication 43 - Monitoring and control subsystem 44 - Antenna control in-orbit testing

TABLE. Indicators of Main Technical Performance of Beijing Maritime Satellite TT&C Station

项目	技术性能指标			
	标准测控天线	多功能天线		
	C波段	C波段		L波段
	测控	测控	在轨测试	在轨测试
使用频段 (MHz)	发：6170～6180 收：3945～3955	发：6170～6180 收：3945～3955	发：6413～6453 收：3565～3655	发：1624～1650 收：1504～1572
信标频率 (MHz)	发：6171.3或6178.7 收：3947.0，3949.4 3950.6，3953.0	发：6171.3或6178.7 收：3947.0，3949.4 3950.6，3953.0		
指向/跟踪精度	0.03度/0.02度	0.02度/0.01度		
轴比	1.09	1.06		1.10
G/T值	31dB/K	32.4dB/K		17.0dB/K
EIRP值	86dBW	89dBW		70dBW
相位噪声	1kHz 10kHz 100kHz −82dBc −92dBc −102dBc		10Hz 100Hz 1000Hz −42dBc −62dBc −82dBc	
增益稳定度	±0.5dB/天			
频率漂移度	±1×10⁻⁹/月			
群延迟稳定度	5ns/24h；3ns/（±400kHz）（绕中心频率）			
5MHz频率源稳定度	±1×10⁻⁹/天			
通信线路误码率	BER（端到端）：1×10⁻⁵			
测控链路可用度	99.95%/年			
通信线路可用度	99.98%/年			

KEY: 1 - Item 2 - Indicators of technical performance 3 - Standard measurement and control antenna 4 - Multi-functional antenna 5 - C-band 6 - L-band 7 - Measurement and control 8 - In-orbit testing 9 - Frequency band used 10 - Transmission 11 - Receiving 12 - Signal marking frequency 13 - Orientation/tracking precision 14 - 0.03^0-0.02^0 15 - $0.02^0/0.01^0$ 16 - Access ratio 17 - Value 18 - Phase noise 19 - Gain stability 20 - Day 21 - Frequency drift 22 - Month 23 - Group delay stability 24 - Around-the-center frequency 25 - Frequency source 26 - Stability 27 - Code error rate of communication circuits 28 - Terminal-to-terminal 29 - Serviceability of measurement and communication chain 30 - Year 31 - Serviceability of communication circuitry

4. High precision of marking and calibration

The related equipment items and components for in-orbit testing should be calibrated to within plus or minus 0.2dB; the technical quality should be at the state-level standard.

5. High "transparency" of the TT&C station

Remote control, telemetry, and tracking measurement should be capable of reliably conducting remote control from the London Satellite Control Center to the satellite via the station, and from the satellite to the station via the London Satellite Control Center. Especially, the Satellite Control Center can execute remote control of orientation, tracking, and in-orbit testing of the multi-function antenna.

6. Complete technical documentation of various kinds

This station strictly conforms with the international specifications in compiling and filing large quantities of contract documents, such as, technical attachments, station documents, system documents, operational and maintenance manuals, daily operation/maintenance documents, reports and tables, and plans.

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